The Atom: From Philosophical Idea to Scientific Theory

DIRECTIONS: Write on the line at the right of each statement the letter preceding the word or expression that best completes the statement.

1. The schoolteacher who studied atoms and proposed an atomic theory was (a) John Dalton; (b) Jöns Berzelius; (c) Johann Dobereiner; (d) Dmitri Mendeleev. _____ 1
2. According to Dalton's atomic theory, atoms (a) are destroyed in chemical reactions; (b) can be subdivided; (c) of a particular element are identical in size, mass, and other properties; (d) of different elements cannot combine. _____ 2
3. One part of Dalton's atomic theory that has been modified is the idea that (a) all matter is composed of atoms; (b) atoms of different elements have different properties and masses; (c) atoms can combine in chemical reactions; (d) atoms cannot be subdivided. _____ 3
4. Dalton's atomic theory did not explain (a) whole-number ratios; (b) definite proportions; (c) conservation of mass; (d) conservation of energy. _____ 4
5. The law of definite composition (a) contradicted Dalton's atomic theory; (b) was explained by Dalton's atomic theory; (c) replaced the law of conservation of mass; (d) assumes that atoms of all elements are identical. _____ 5
6. The fact that lead forms two oxides of different formulas, PbO and PbO_2, is an example of the (a) periodic law; (b) law of multiple proportions; (c) atomic law; (d) law of conservation of mass. _____ 6

The Structure of the Atom

DIRECTIONS: Write on the line at the right of each statement the letter preceding the word or expression that best completes the statement.

1. In early experiments on electricity and matter, electrical current was passed through a glass tube containing (a) water; (b) gas under high pressure; (c) liquid oxygen; (d) gas under low pressure. _____ 1
2. As a result of the movement of a paddle wheel placed between the electrodes in a glass tube through which electrical current passed, scientists concluded that (a) a magnetic field was produced; (b) particles were passing from the cathode to the anode; (c) there was gas in the tube; (d) atoms were indivisible. _____ 2
3. Since most particles fired at metal foil pass through the foil, it may be concluded that (a) atoms are mostly empty space; (b) atoms contain no charged particles; (c) electrons form the nucleus; (d) atoms are indivisible. _____ 3
4. Since a few positively-charged particles bounce back from metal foil, it may be concluded that (a) an atom is indivisible; (b) electrons make up the center of atoms; (c) an atom carries a positive charge; (d) an atom contains a small, dense, positively-charged central region. _____ 4
5. The nucleus of an atom has all of the following characteristics EXCEPT that it (a) is positively charged; (b) is very dense; (c) contains nearly all of the atom's mass; (d) contains nearly all of the atom's volume. _____ 5
6. An atom is electrically neutral because (a) neutrons balance the protons and electrons; (b) nuclear forces equalize the charges; (c) the number of protons and electrons is equal; (d) the number of protons and neutrons is equal. _____ 6

Dalton's atomic theory

The atomic theory proposed by Dalton in the early 19th century has been modified somewhat over the years. However, its principles still form the basis for our current understanding of the nature of matter.

Matter consists of extremely small particles called _____.
Atoms of the same element are nearly _____ in their properties.
Atoms of different elements are _____ in their properties.
Chemical reactions represent the _____ or _____ of atoms.
During chemical reactions, atoms are neither _____ nor _____.

SHORT ANSWER Answer the following questions in the space provided.

1. Why is Democritus's view of matter considered only an idea, while Dalton's view is considered a theory?

2. Give an example of a chemical or physical process that illustrates the law of conservation of mass.

3. State two principles from Dalton's atomic theory that have been revised as new information has become available.

4. The formation of water according to the equation

$$2H_2 + O_2 \rightarrow 2H_2O$$

shows that 2 molecules (made of 4 atoms) of hydrogen and 1 molecule (made of 2 atoms) of oxygen produce 2 molecules of water. The total mass of the product, water, is equal to the sum of the masses of each of the reactants, hydrogen and oxygen. What parts of Dalton's atomic theory are illustrated by this reaction? What other law does this reaction illustrate?

In cathode ray tubes, the cathode ray is emitted from the negative electrode, which is called the _____.

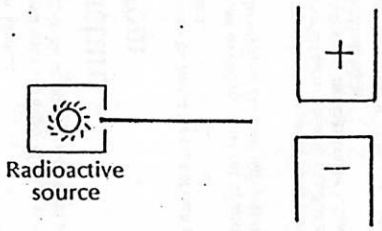
The smallest unit of an element that can exist either alone or in combination with atoms of the same or different elements is the _____.

A positively charged particle found in the nucleus is called a(n) _____.

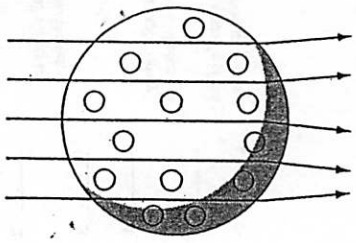
A nuclear particle that has no electrical charge is called a(n) _____.

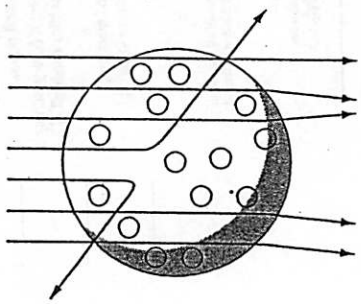
The subatomic particles that are least massive and most massive, respectively, are the _____ and _____.

Beams of protons, electrons, and neutrons behave differently as they pass through charged plates. On the following drawing, sketch the paths of each kind of beam, and label each one.



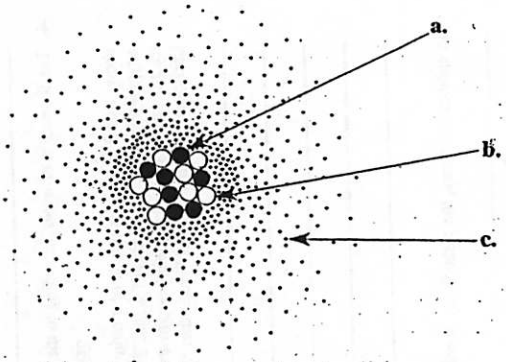
Below are two illustrations of scientists' conception of the atom. Label the electrons with a − sign and the nucleus with a + sign. On the line below the figures, identify which illustration was believed to be correct before Rutherford's gold foil experiment and which was believed to be correct after Rutherford's gold foil experiment.





a. _____ b. _____

In the space provided, describe the locations of the subatomic particles in the labeled model of the atom below and the charge and relative mass of each particle.



a. proton

b. neutron

c. electron

Name_____ Date_____ Class _____

3–3 Practice Problems

1. How many protons and electrons are present in a vanadium atom?

2. How many protons and electrons are present in a nitrogen atom?

3. How many protons and electrons are present in an argon atom?

4. How many protons and electrons are present in a potassium atom?

5. How many protons and electrons are present in a platinum atom?

6. What is the name of the element that has atoms that contain 5 protons?

7. What is the name of the element that has atoms that contain 17 protons?

8. What is the name of the element that has atoms that contain 25 protons?

9. What is the name of the element that has atoms that contain 82 protons?

10. What is the name of the element that has atoms that contain 92 protons?

11. Write the chemical symbol for the ion with 12 protons and 10 electrons.

12. Write the chemical symbol for the ion with 74 protons and 68 electrons.

13. Write the chemical symbol for the ion with 95 protons and 89 electrons.

14. Write the chemical symbol for the ion with 33 protons and 36 electrons.

Name_____ Date_____ Class _____

3–3 *Practice Problems (continued)*

15. Write the chemical symbol for the ion with 29 protons and 27 electrons.

16. How many protons, neutrons, and electrons are present in the $^{59}_{28}Ni^{2+}$ ion?

17. How many protons, neutrons, and electrons are present in the $^{91}_{40}Zr^{4+}$ ion?

18. How many protons, neutrons, and electrons are present in the $^{140}_{58}Ce^{3+}$ ion?

19. How many protons, neutrons, and electrons are present in the $^{79}_{34}Se^{2-}$ ion?

20. How many protons, neutrons, and electrons are present in the $^{45}_{21}Sc^{3+}$ ion?

21. How many protons, neutrons, and electrons are present in the $^{13}_{6}C^{4-}$ ion?

22. Write the complete chemical symbol for the ion with 84 protons, 125 neutrons, and 80 electrons.

23. Write the complete chemical symbol for the ion with 27 protons, 32 neutrons, and 25 electrons.

24. Write the complete chemical symbol for the ion with 73 protons, 108 neutrons, and 68 electrons.

25. Write the complete chemical symbol for the ion with 31 protons, 39 neutrons, and 28 electrons.

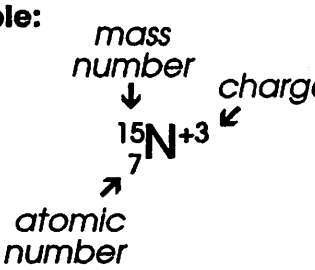
ATOMIC STRUCTURE

Name _____

An atom is made up of protons and neutrons (both found in the nucleus) and electrons the surrounding electron cloud). The atomic number is equal to the number of protons. The mass number is equal to the number of protons plus neutrons. In a neutral atom, the number of protons equals the number of electrons. The charge on an ion indicates an imbalance between protons and electrons. Too many electrons produces a negative charge, too few, a positive charge.

This structure can be written as part of a chemical symbol.

Example:



7 protons
8 neutrons (15 - 7)
4 electrons

Complete the following chart.

Element/ Ion	Atomic Number	Atomic Mass	Mass Number	Protons	Neutrons	Electrons
H						
H^+						
$^{12}_{6}C$						
$^{7}_{3}Li^+$						
$^{35}_{17}Cl^-$						
$^{39}_{19}K$						
$^{24}_{12}Mg^{2+}$						
As^{3-}						
Ag						
Ag^{+1}						
S^{-2}						
U						

A.5 BUILDING SKILLS SUPPLEMENT: FINDING AVERAGE ATOMIC WEIGHT

Example: There are three isotopes of neon found on the earth: ^{20}Ne that accounts for 90.92% of the total, ^{21}Ne, which makes up 0.2571%, and ^{22}Ne, which makes up 8.822%. What is the average atomic weight of Ne?

Atomic weight = (weight of isotope) × (decimal of percent) + (weight of isotope) × (decimal of percent) + . . .
= (20) × (0.9092) + (21) × (0.002571) + (22) × (0.08822)
= 18.1840 + 0.053991 + 1.94084
= 20.1788 (rounded to least decimal place)

1. ^{10}B (19.78%), ^{11}B (80.22%)

2. ^{63}Cu (69.46%), ^{65}Cu (30.54%)

3. ^{69}Ga (60.27%), ^{71}Ga (39.73%)

4. ^{79}Br (50.42%), ^{81}Br (49.58%)

5. ^{85}Rb (72.10%), ^{87}Rb (27.90%)

6. ^{35}Cl (77.30%), ^{37}Cl (22.70%)

7. ^{107}Ag (51.72%), ^{109}Ag (48.28%)

8. ^{28}Si (92.2%), ^{29}Si (4.7%), ^{30}Si (3.1%)

9. ^{24}Mg (78.70%), ^{25}Mg (10.13%), ^{26}Mg (11.17%)

7. How many neutrons are in each of the following isotopes? → electron, proton, neutron

	p	n	e
a. titanium-46			
b. plutonium-242			
c. seaborgium-263			
d. tungsten-186			

AE

The Atomic Mass of 'Noodlium'

The atomic mass of an element recorded in the periodic table represents the average atomic mass of all the naturally occurring isotopes of that element. This average is calculated based on the mass number and the relative abundance of each of the isotopes. Therefore, the atomic mass of an element is not a whole number since it is the weighted average of the masses of the different isotopes. All atoms of the same element have the same number of protons in their nuclei but the number of neutrons may vary. Since each neutron has an atomic mass unit of 1 amu this will result in atoms with different atomic masses but the same number of protons. The atomic masses of atoms do not increase regularly as their atomic numbers increase because their neutrons increase irregularly.

In this activity you will be given a sample of mixed types of pasta noodles, which serve to represent the isotopes of noodles. By determining the percent abundance and the unit mass of each type of noodle, you will be able to calculate the atomic mass of 'noodlium'. By doing this activity, you will begin to understand the concept of average atomic mass of and element and why the atomic masses of some elements are not whole numbers.

Materials and Equipment

- Scale or triple beam balance
- A variety of pasta noodles
- 1 large polystyrene cup

Procedure

1. Obtain a sample of 'noodlium' from your teacher. The sample contains a mixture of different isotopes, i.e. pasta noodle varieties. The sample should contain 100 noodles in total.

2. Measure and record the total mass of the sample in the cup. _____ g

3. Carefully empty the contents into a large flat surface. Measure the mass of the empty cup. Subtract this empty cup mass from the total mass to give the mass of the sample alone. _____ g

4. Sort and record the pasta noodles by type (shape). Check the total number of noodles.

5. Find the mass of a pasta noodle of each type. Determine the average by measuring the mass of 10 noodles of each type and dividing by 10.

	Type of noodle	Average mass (g)
a.		
b.		
c.		
d.		

6. Calculate the percentage of each noodle type (isotope) in the sample, using the formula:

% abundance = # of noodles of a given type/ 100

	Type of noodle	% Abundance
a.		
b.		
c.		
d.		

7. Determine the weighted average atomic mass for noodlium using the formula: $\{[mass_a \times (\%)_a] + [mass_b \times (\%)_b] + [mass_c + (\%)_c] + [mass_d \times (\%)_d]\} \div 100$

Weighted average mass of noodlium is:_____

Questions

1.) Is your weighted average mass consistent with the total sample mass?

2.) Define isotope. Explain the differences between neon-19, neon-20, and neon-22.

3.) The following are natural isotopes of magnesium. Calculate the average atomic mass of magnesium given the following % abundance.

- Mg-24, 78.99%
- Mg-25, 10.00%
- Mg-26, 11.01%

Moles and Atoms Worksheet

1. How many moles are there in 45.0 g of iodine (diatomics)?

2. How many moles are there in 560. g of barium?

3. How many moles are there in 0.230 g of lead?

4. How many grams are there in 56.0 mol of iodine (diatomics)?

5. How many grams are there in 0.0600 mol of sulfur?

6. How many grams are there in 2345 mol of helium?

7. How many atoms are there in 45.0 mol of lead?

8. How many atoms are in 89.0 mol of lead? In 89.0 mol of phosphorous? In 89.0 mol of copper?

9. How many atoms are in 56.0 g of mercury?

10. How many atoms are there in 0.0790 g of lithium?

THE MOLE AND AVOGADRO'S NUMBER

Name _____

One mole of a substance contains Avogadro's Number (6.02×10^{23}) of molecules.

How many atoms are in the quantities below?

1. 2.0 moles
2. 1.5 moles
3. 0.75 mole
4. 15 moles
5. 0.35 mole

How many moles are in the number of atoms below?

1. 6.02×10^{23} atoms
2. 1.204×10^{24} atoms
3. 1.5×10^{20} atoms
4. 3.4×10^{26} atoms
5. 7.5×10^{19} atoms

Convert the following amounts. Show all work with units.

2.5 mol K= _____?_____ atoms K

$2.5 \text{ mol K} \times \frac{6.022 \times 10^{23} \text{ atoms K}}{1 \text{ mol K}} = 1.5 \times 10^{24} \text{ atoms K}$

3.1 mol Ca = _____?_____ atoms Ca

$3.1 \text{ mol Ca} \times \frac{6.022 \times 10^{23} \text{ atoms Ca}}{1 \text{ mol Ca}} = 1.87 \times 10^{24} \text{ atoms Ca}$

5.2×10^{24} atoms O = _____?_____ mol O

$5.2 \times 10^{24} \text{ atoms O} \times \frac{1 \text{ mol O}}{6.022 \times 10^{23} \text{ atoms O}} = 8.6 \text{ mol O}$

4.2×10^{23} atoms N = _____?_____ mol N

$4.2 \times 10^{23} \text{ atoms N} \times \frac{1 \text{ mol N}}{6.022 \times 10^{23} \text{ atoms N}} = 0.70 \text{ mol N}$

Convert the following amounts. Show all work with units.

2.5 mol K= _____?_____ atoms K

3.1 mol Ca = _____?_____ atoms Ca

5.2×10^{24} atoms O = _____?_____ mol O

4.2×10^{23} atoms N = _____?_____ mol N

Name_____

Moles-Molar Mass Calculations

Convert the following amounts. Show all work with units. You may use a periodic table.

9.5 mol Ca= _____?_____ g Ca

6.2 mol F = _____?_____ g F

4.5 mol Ar = _____?_____ g Ar

9.0 mol Li= _____?_____ g Li

1.2 g O = _____?_____ mol O

2.5 g K = _____?_____ mol K

49 g F = _____?_____ mol F

500 g B = _____?_____ mol B

Name_____

Atoms-Mass Calculations

Convert the following amounts. Show all work with units. You may use a periodic table.

Remember when converting between atoms and grams you must go through the mole! Your calculations must be two steps!!

23.0 g Na= _____?_____ atoms Na

6.2 g C = _____?_____ atoms C

4.5 g Ar = _____?_____ atoms Ar

9.0 g Li= _____?_____ atoms Li

1.2×10^{24} atoms O = _____?_____ g O

2.5×10^{23} atoms K = _____?_____ g K

4.9×10^{23} atoms F = _____?_____ g F

5.0×10^{25} atoms B = _____?_____ g B

Name_____

6.022×10^{23}...But how much is a mole??

Purpose: To understand how big a mole actually is, and to understand how small an atom actually is.

Materials:

- 1 (before 1982) penny
- 1 iron nail
- A piece of silicon
- A piece of lead
- Ball of aluminum foil
- A piece of carbon

Procedure:

1. Look at the 6 items gathered above. Make the following predictions making sure to **explain** each. Which one do you think contains the most atoms?

Do you think each item is more or less than 1 mole?

2. Determine the number of moles and the number of atoms in each item. Show your work. Record the results in a data table. (Make sure to show all of your work with units! If you need more room use the back of this paper)

3. Were your predictions correct? Why or why not?

AF

Harder mole concept problems

On one half of a balance is 65 atoms of O, how many C atoms would be needed on the other side of the balance to equal the mass of the O atoms?

How many atoms of platinum (Pt) are present in a cylinder with a diameter of 5.00 cm and a height of 7.00 cm? ($D_{Pt} = 21.4$ g/cm^3)

What volume of copper (D = 8.92 g/cm^3) would have the same number of platinum atoms that are in the above question?

Harder mole concept problems

H

On one half of a balance is 65 atoms of O, how many C atoms would be needed on the other side of the balance to equal the mass of the O atoms?

How many atoms of platinum (Pt) are present in a cylinder with a diameter of 5.00 cm and a height of 7.00 cm? ($D_{Pt} = 21.4\ g/cm^3$)

What volume of copper ($D = 8.92\ g/cm^3$) would have the same number of platinum atoms that are in the above question?

How much heat energy would be absorbed by 1.52×10^{25} atoms of copper ($Cp = 0.385\ J/g°C$) that went from 36.5°F to 120.°F?

Name _____ Date _____ Class _____

CHAPTER 3 REVIEW

Atoms: The Building Blocks of Matter

SECTION 3-3

SHORT ANSWER Answer the following questions in the space provided.

1. Explain the difference between the *mass number* and the *atomic number* of a nuclide.

2. Why is it necessary to use the average atomic mass of all isotopes rather than the mass of the most commonly occurring isotope when referring to the atomic mass of an element?

3. How many particles are in 1 mol of carbon? 1 mol of lithium? 1 mol of eggs? Will 1 mol of each of these substances have the same mass?

4. As the atomic masses of the elements in the periodic table increase, what happens to each of the following:

   a. the number of protons

   b. the number of electrons

   c. the number of atoms in 1 mol of each element

Name _____ Date _____ Class _____

SECTION 3-3 continued

5. Complete the following table:

Element	Symbol	Atomic number	Mass number
Europium-151			
	$^{109}_{47}Ag$		
Tellurium-128			

6. List the number of protons, neutrons, and electrons found in zinc-66.

   _____ protons

   _____ neutrons

   _____ electrons

PROBLEMS Write the answer on the line to the left. Show all your work in the space provided.

7. _____ What is the mass in grams of 2.000 mol of oxygen atoms?

8. _____ How many moles of aluminum exist in 100.0 g of aluminum?

9. _____ How many atoms are in 80.45 g of magnesium?

10. _____ What is the mass in grams of 100 atoms of the carbon-12 isotope?

Name _____ Date _____ Class _____

CHAPTER 3 REVIEW

Atoms: The Building Blocks of Matter

MIXED REVIEW

SHORT ANSWER Answer the following questions in the space provided.

1. The element boron, B, has an atomic mass of 10.81 amu according to the periodic table. However, no single atom of boron has a mass of exactly 10.81 amu. How can you explain this difference?

2. How did the outcome of Rutherford's gold foil experiment indicate the existence of a nucleus?

3. The ibuprofen, $C_{13}H_{18}O_2$, that is manufactured in Michigan contains 75.69% carbon, 8.80% hydrogen, and 15.51% oxygen. If you buy some ibuprofen for a headache while you are on vacation in Germany, how do you know that the ibuprofen you buy at a pharmacy overseas has the same percentage composition as the one you buy at home?

4. Complete the following chart using the atomic mass values from the periodic table:

Compound	Mass of Fe (g)	Mass of O (g)	Ratio of O:Fe
FeO			
Fe_2O_3			
Fe_3O_4			

Name _____ Date _____ Class _____

MIXED REVIEW continued

5. Complete the following table:

Element	Symbol	Atomic number	Mass number	Number of protons	Number of neutrons	Number of electrons
Sodium			22			
	F	9	19			
			80		45	
			40	20		
		1			0	
			222			86

PROBLEMS Write the answer on the line to the left. Show all your work in the space provided.

6. _____ a. How many atoms are there in 2.50 mol of hydrogen?

_____ b. How many atoms are there in 2.50 mol of uranium?

7. _____ How many moles are present in 107 g of sodium?

8. A certain element exists as three natural isotopes as shown in the table below.

Isotope	Mass (amu)	Percent natural abundance	Mass number
1	19.99244	90.51	20
2	20.99395	0.27	21
3	21.99138	9.22	22

_____ Calculate the average atomic mass of this element.